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Long-term intraoral findings in humans after exposure to total-body irradiation from sudden radioactive fallout. I. Five year postdetonation studies

Significant quantities of radioactive fallout precipitated on Rongerik atoll, Rongelap atoll, Ailingnae and Uterik in the Marshall Islands after detonation of a 15 megaton thermonuclear test device at the Bikini Proving Grounds in February 1954. As a result, 239 Marshallese were accidentally exposed to total-body irradiation ranging from 14 to 175 R. Five years later, dental examinations were conducted in conjunction with medical examinations to investigate the morphological effects of the exposure. The initial dental survey reported here showed no significant differences in caries rate or prevalence of periodontal disease in irradiated and non-irradiated groups. However, the degree of periodontal destruction was more extensive in the Rongelapese who received the heaviest exposure to radioactive fallout (175 R).

Information concerning long-term morphological effects from total body irradiation in humans is relatively scant. Specific data pertaining to these effects on hard and soft oral tissues are even less available. Sequelae of locally applied ionizing radiation to human oral tissues are well known; however, limitations to long-term intraoral observations in total-body-irradiated patients are determined only by the number of survivors. Three population groups offer opportunity for further study: inhabitants of Hiroshima and Nagasaki, certain Marshall Island populations and laboratory personnel involved in nuclear criticality reactions.

This report describes those intraoral clinical findings obtained in March 1959 by a combined medicodental survey team on groups of Marshallese people five years after exposure to total body irradiation from sudden, significant quantities of radioactive fallout.

BACKGROUND

Initial exposure occurred after detonation of a 15 megaton thermonuclear test device at the Bikini Proving Grounds in February 1954. Because of an unusual shift in winds, varying quantities of fallout matter were deposited on and in

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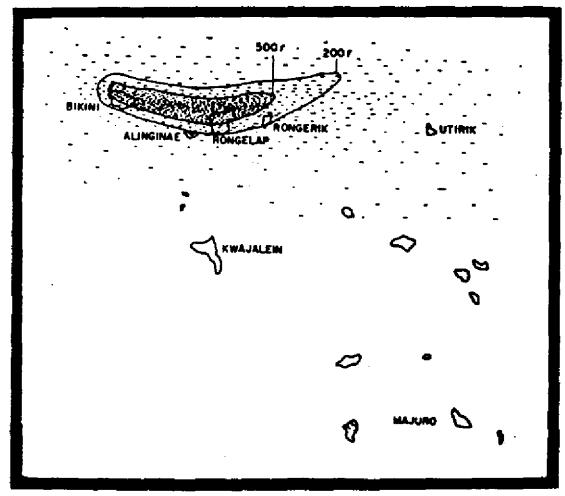

Fig. 1 • Map of Marshall Islands showing fallout area (broken lines). Rongelap inhabitants were located at southernmost portion of atoll

the vicinity of four inhabited Marshall Islands. As a result 23 Japanese fishermen aboard the *Lucky Dragon,* 28 United States servicemen stationed on Rongerik atoll, and 239 Marshallese were exposed to ionizing radiations from radioactive fallout.[1] Sixty-four inhabitants of Rongelap atoll (Fig. 1), located 105 miles from the detonation site, received the heaviest exposure to fallout—an estimated 175 R total body gamma irradiation, contamination and subsequent beta burns of the skin, and some internal absorption of radioactive material.[2] On adjacent Ailingnae Island, an additional group of 18 Rongelapese received about half this exposure. Approximately the same amount, 70 R, was received by 28 U. S. servicemen stationed on Rongerik atoll. Fallout also was deposited on Uterik Island, 200 miles from Bikini. On Uterik, 157 Marshallese were subjected to about 14 R whole-body gamma irradiation.

NATURE OF FALLOUT

According to Conard,[3] fallout of radioactive material on Rongelap was observed approximately 4 to 6 hours after detonation. This material consisted mainly of calcium oxide from incinerated coral plus adherent fission products. On Rongelap, the most heavily contaminated island, fallout was a snowlike powder. It fell over a period of several hours, whitening the hair and adhering to the skin. Fallout on Rongerik and Ailingnae was mistlike in appearance and on Uterik, it was invisible.

THERAPY AND SUBSEQUENT COURSE OF EVENTS

Exposed inhabitants of these islands were transported to nearby Kwajalein Naval Base two days after the detonation. At the base, they received extensive care for a period of three months; however, dental examinations and records were not obtained at this time.

Three months after the thermonuclear detonation, radiation surveys of these previously inhabited islands showed that only Rongelap was highly contaminated. Radioactivity in the other islands was low enough for safe habitation. The American servicemen were returned to their duty stations because of generally negative findings. The Uterik people also were allowed to return to their home island. Because Rongelap atoll was considered to be too highly contaminated, the Rongelap people were taken to

Majuro, where they lived for three and one-half years. They were examined yearly by a medical team.

Control Population • Three years after the thermonuclear detonation, it was found that the Rongelap population had doubled on Majuro because of an influx of relatives and in-laws from other islands not exposed to fallout. This nonexposed population was selected to serve as a control group because they were of the same genetic stock, comparable size, and similar age and sex distribution. Thus, four distinct population samples were available for comparative study: three exposed groups that received 175, 70 and 14 R, respectively, and a nonirradiated control population.

Summary of Past Medical Findings • Reports of previous medical findings concerning these irradiated population groups have been published;[4-9] however, a brief summary of this background material is pertinent for correlation with certain intraoral findings obtained during this current survey.

Rongelap Population • Shortly after contamination of the island by fallout matter, the more heavily irradiated Rongelap people (175 R) showed typical symptoms of acute radiation sickness. Within 48 hours, about two thirds of this group experienced anorexia and nausea, a few vomited and others complained of diarrhea. Many developed itching of the skin and burning sensations in the eyes with subsequent lacrimation. Two weeks later, skin lesions from beta radiation burns and loss of body hair became evident. Lymphocyte counts showed considerable depression a few days after exposure. Radiochemical analyses of urine showed that measurable amounts of radioactive material had been absorbed internally.

It was apparent that the Rongelap group had been exposed to three types of radiation energy: whole-body penetration, localized skin irradiation, and internal absorption of radioactive substances. The irradiation dose proved to be sublethal since no deaths occurred from direct exposure to radiation; however, dosage was judged to be in the high sublethal range because of the degree of developing hemopoietic depression it caused.

Penetrating gamma radiations caused severe effects in peripheral blood elements. Lymphocyte levels fell rapidly and by the third day were 55 per cent of the control values. There was only slight recovery after six months, and after four years, the mean level was about the same as the control group. Neutrophil levels also fell to 50 per cent but returned to normal after one year. Platelet levels fell to about 30 per cent by the fourth week but reached 70 per cent of the control values after six months. After four years, the platelet level still was below that of the control population.

During the first few days after initial exposure to fallout, maximum permissible body levels of internally absorbed radioactive fission products were approached or exceeded only in the case of strontium-89 and the isotopes of iodine. Body levels fell rapidly and three years postexposure, they were far below the accepted maximum permissible level. At the present time, it is thought that the original body burdens appear to be too low to have produced or to cause any long-term effects.

Certain clinical observations are difficult to evaluate. Studies on height, weight and bone age in children seemed to show some retardation in growth and development; however, no effect in either eruption time of deciduous and permanent teeth or changes in rate of jaw growth were noted during this present examination.

Ailingnae and Uterik Population • These population groups received 70 R and 14 R total-body irradiation, respectively. Although there was evidence of

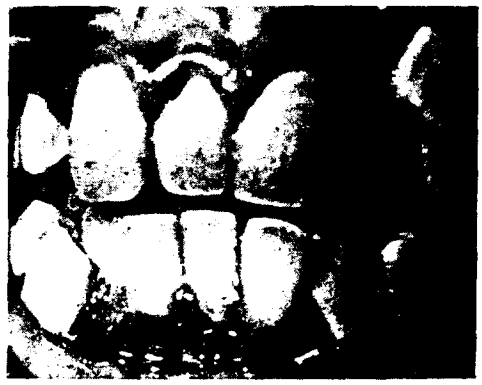

Fig. 2 • Unilateral narrow maxillary central incisor in 11 year old Majuro boy

slight hemopoietic depression in the Ailingnae group, most of these people remained asymptomatic. No effects were noted in the population residing on Uterik island.

PRESENT HEALTH STATUS

Results of the 1959 medical survey showed that the Marshallese people had recovered from the acute effects of radiation exposure and appeared to be in good health. Previous examining teams concerned with growth and development studies of Marshallese children were uncertain as to whether certain anomalies in dentition and jaw growth, such as peg-shaped central incisors, supernumerary teeth, variations in malocclusion, were associated with radiation exposure. For this reason, a dental team was invited to participate in the 1959 survey. This factor plus the opportunity to evaluate and compare oral conditions in irradiated and nonirradiated population groups five years after initial exposure form the basis for this report.

DENTAL SURVEY OF MARSHALLESE POPULATIONS

Initial dental examinations were conducted as an integral part of the 1959 medical survey, using routine methods and instruments. Oral conditions were determined by the use of mouth mirrors, sharp explorers and pocket measuring probes and were recorded on the Standard Dental Form, DD 603. Intraoral roentgenograms were not taken because of the patients' former exposure to gamma radiation. Graded pHydrion paper, range 6.0 to 8.0 was used intraorally to record approximate salivary pH values. Samples of whole saliva, salivary calculus and extracted teeth were collected for future radiochemical analyses.

In that few Rongelapese people speak English and many were uncertain of their true age, it was difficult to conduct examinations and obtain vital statistics. These factors combined to make an ideal blind system impractical. Consequently, evaluation of recorded data was difficult; it was impossible to eliminate any biases perceived by the examiner. The extent of periodontal destruction in adults was judged according to the impression received by the evaluator. No DMF system or periodontal index was used in this initial survey.

Majuro Populations • Before visiting the irradiated Marshallese populations, several members of the dental team went to the island of Majuro to examine nonirradiated children participating in current growth and development studies. Thirty of these children and about the same number of adults were examined to gain familiarization with Marshallese dentition.

A high caries incidence was noted in the children, and most adults showed evidence of periodontal disease. Many of the children had retained deciduous crown fragments in the gingival crevice adjacent to erupting permanent teeth. Bunched lower incisors with subsequent narrowing of the mandibular symphysis and premature loss of deciduous molars were commonly found. Other anomalies noted were the presence of unilateral narrow permanent maxillary central incisors, (Fig. 2) and the presence of pigmented hypoplas-

tic enamel lesions in deciduous incisors. According to the local dental practitioners, these conditions, with the exception of the high caries incidence, are common to all Marshallese population groups.

Irradiated and Control Populations • Using local facilities and interpreters, the medicodental team carried out complete physical examinations in Rongelap. Emergency dental treatment was administered during the course of examination procedures. After completing examinations in Rongelap, the team proceeded to Uterik to finish the study.

RESULTS

Patient data were arranged according to age groups (table). Certain aspects require further elaboration, as follows:

Caries and Developmental Growth •

1. Rongelap children ages 1 to 5 born of irradiated parents:

As of March 1959, 16 children had been born of parents receiving the highest total body radiation dose (175 R). One child, born of parents receiving 70 R, was in the third trimester at the time of exposure. Of the irradiated Rongelap group, three children were in utero at the time of initial exposure—two in the third trimester, and one in the first. Of 15 children examined, carious lesions were present in five patients (33 per cent), averaging 3 carious teeth each. No abnormalities in tooth form, jaw morphology or growth and development of the oral structures that differed from the children of nonirradiated parents were observed in these patients.

2. Rongelap control children, ages 1 to 5 years, born of nonirradiated parents:

Dental caries was present in 11 (39 per cent) of the 28 children in this group. These 11 children averaged four carious teeth each. Tooth form, jaw morphology and growth patterns were similar to those in the children born of irradiated parents.

3. Rongelap irradiated children, 6 to 18 years old:

Of 25 patients, dental caries was present in 16 children (64 per cent), averaging 3.3 carious teeth each. There was no visible evidence of radiation injury or alteration in morphology in teeth which had erupted since exposure to fallout.

4. Rongelap control children, 6 to 18 years old:

Dental caries was present in 18 of the 35 children (51 per cent) in this group. These 18 children averaged 3.2 carious teeth each.

5. Uterik children, ages 1 to 5 years, born of irradiated parents (14 R):

Of 21 children examined, dental caries was present in eight subjects (38 per cent). One child had 22 decayed teeth; the remaining seven averaged 4.3 carious teeth each.

6. Irradiated Uterik children (14 R), ages 6 to 18 years:

Dental caries was present in 14 of the 36 children examined (39 per cent). The average for these 14 subjects was 3.0 carious teeth each.

7. Rongelap irradiated adults, ages 19 to 35 years:

Fifteen (79 per cent) of 19 patients had dental caries with an average of 2.3 decayed teeth each.

Table • Dental caries activity in radiated and nonirradiated patients

POPULATION GROUP	NUMBER OF PATIENTS	NUMBER WITH CARIES	PERCENT WITH CARIES	NO. LESIONS PER PATIENT WITH CARIES	AVERAGE NO. LESIONS PER POP. GROUP
(1)RONGELAP CHILDREN, AGES 1-5 born of radiated parents (175r)	15	5	33	3.0	1.0
(2)RONGELAP CHILDREN, AGES 1-5 born of non-radiated parents	28	11	39	4.0	1.6
(3)RONGELAP RADIATED CHILDREN (175r) AGES 6-18	25	16	64	3.3	2.0
(4)RONGELAP CHILDREN non-radiated AGES 6-18	35	18	51	3.2	1.6
(5)UTERIK CHILDREN, AGES 1-5 born of radiated parent (14r)	21	8	38	6.5*	2.5
(6)UTERIK-RADIATED CHILDREN, AGES 6-18	36	14	39	3.0	1.2
(7)RONGELAP ADULTS, RADIATED (175r) AGES, 19-35	19	15	79	2.3	1.8
(8)RONGELAP ADULTS, NON-RADIATED AGES 19-35	35	20	57	2.8	1.6

* One child had 22 lesions; The remaining seven averaged 4.2 lesions

Fig. 3 • Chronic inflammatory destructive periodontitis in 48 year old radiated Rongelap man

8. Rongelap nonirradiated adults, ages 19 to 35 years:

Examination of this group revealed that 20 (57 per cent) of 35 patients had an average of 2.8 carious teeth each.

The foregoing findings show that the prevalence of caries was slightly higher in the irradiated Rongelap children and younger adults than in the nonirradiated control group, with the exception of the children born of irradiated parents.

Periodontal Findings • The level of periodontal destruction was greater in the irradiated Rongelap adults than in the comparative control population. In both population groups, minimal lesions such as asymptomatic, nonspecific marginal gingivitis and the soft tissue symptoms of traumatic occlusion were categorized as disease-free. Chronic advanced periodontal disease was classified as varying degrees of chronic inflammatory destructive periodontitis. Figure 3 shows a typical instance of advanced periodontitis. Among the 44 irradiated adults, 19 years and older, 14 (32 per cent) were edentulous as compared to 18 (21 per cent) of the 83 nonirradiated subjects in the same age group. Of the remaining 30 irradiated adults, 19 (63 per cent) had conditions judged to be advanced chronic periodontal disease. Similar levels of periodontal destruction were observed in 22 (35 per cent) of the 65 nonirradiated patients. One 40 year old irradiated adult had concurrent, active subgingival and supragingival calculus deposition and severe caries activity (Fig. 4).

Miscellaneous Findings • Many of the irradiated and nonirradiated Rongelap children exhibited oral conditions similar to those seen in the Majuro subjects; namely, crowding of the erupting permanent lower anterior teeth with retention of deciduous lateral incisors, hypoplasia and pigmentation of the maxillary central and lateral incisors. Prevalence of these conditions was not limited to either the irradiated or the nonirradiated groups.

Almost all irradiated and nonirradiated Rongelapese exhibited pronounced xerostomia. During intraoral examination, manipulation of the tissues failed to stimulate the flow of saliva. The mucosa was moist but not wet. When recording pH samples, it was necessary to allow the paper strip to remain in the floor of the mouth for at least 30 seconds. No significant differences in salivary pH levels were noted between the irradiated and nonirradiated groups.

No evidence of intraoral neoplasm was noted; however, one 42 year old irradiated Rongelap man had a small leukoplakic-like lesion on the gingiva immediately distal to the mandibular left third molar.

Fig. 4 • Concurrent presence of rampant caries with active subgingival and supragingival calculus formation in 40 year old radiated man. Note cervical amputation of maxillary incisors caused by caries

DISCUSSION

The acute effects of significant quantities of total-body ionizing radiations on human oral tissues have been described.[10-16] Postirradiation findings from high radiation levels include hemorrhagic gingivitis, buccopharyngeal ulceration and necrotizing gingivitis. According to Gerstner,[16] these lesions develop only when the total body dose exceeds 250 R. None of the foregoing acute conditions was noted in any of the irradiated Rongelapese.

Any relation of radiation exposure in the Rongelap people to the somewhat higher levels of periodontal destruction in this group is purely conjectural. Because of the generally substandard levels of oral hygiene among the Marshallese, it appears likely that the disease was prevalent in the Rongelap group at the time of their radiation exposure. It is possible to speculate that the period of leukopenia after this group's exposure might have enhanced the progress of periodontal disease. Clinically, however, they showed no evidence of increased infection, oral or otherwise, nor bleeding tendency during the period of leukopenia and thrombocytopenia. Nevertheless, it is possible that in a subclinical sense radiation exposure might have resulted in lower tissue resistance and repair, thereby enhancing the progress of periodontal disease in this group.

The fact that 64 per cent of the Rongelap irradiated children and 51 per cent of the Rongelap nonirradiated children had experienced dental caries indicates that caries activity was similar in both these groups. However, the available number of subjects was too small to test the possible significance of the difference. A dental survey is planned for the ten year postexposure examinations, which will allow further observations of these dental abnormalities. In addition, the state of dentition in the children will be of interest in view of the findings of slight retardation of growth and development in certain exposed Rongelap children.[17]

The inhabitants of Uterik who received only 14 R have remained completely asymptomatic since initial exposure.

SUMMARY

Initial dental examinations of certain Marshallese populations who were exposed accidentally to significant quantities of ionizing radiations from radioactive fallout were conducted five years after primary exposure. Fortunately, negative findings far outnumber positive observations. The examinations disclosed the following:

1. Similar degrees of caries activity were observed in irradiated and nonirradiated children.
2. Although the prevalence of periodontal disease was practically identical in both the irradiated and nonirradiated groups, the extent of periodontal destruction was greater in the irradiated Rongelapese. This difference may or may not be related to factors such as leukopenia and lower tissue resistance and the presence of preexisting periodontal disease.
3. Children born of irradiated parents, including those children in utero at the time of initial exposure, and irradiated children 6 to 18 years old, showed no evidence of any morphological effects on oral tissues from total body irradiation when compared with the nonirradiated control groups.

The opinions or assertions contained in this article are the private ones of the writer and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

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